Annual Progress Report - July 2000
ARM Science Team

1. Principal Investigators:

Brooks E. Martner and Kenneth P. Moran
Environmental Technology Laboratory
Boulder, Colorado

2. Title

Optimization of the Scientific Performance of CART Cloud Radars
(Project ER-62362)

3. Goals

The common purpose of several activities in this project is to continue to refine and improve the usefulness of the ARM millimeter-wave cloud radars (MMCR) and the quality of their measurements through development and testing of advanced radar techniques. The work focuses on calibration techniques, improved operating modes, microphysical retrieval techniques and methods to ameliorate insect contamination of cloud signals. The following paragraphs describe activities conducted in the last year at NOAA/ETL, including collaborations with other ARM scientists.

4. Accomplishments

- Participation in the March 2000 Cloud IOP with the scanning NOAA/K cloud radar
- Dual-antenna development and testing for improved calibrations
- Field maintenance and upgrades
- Y2K upgrades for all MMCRs
- Analytical assessment of polarization measurements for insect identification
- Continued work on microphysical retrievals involving cloud radar data
- Publications.

5. Progress in Last 12 Months

5a. IOP Participation

ETL operated its NOAA/K scanning cloud radar during the last two weeks of the March 2000 IOP and for another week thereafter at the Central Facility of the SGP CART site. The primary objective of the IOP was to assess the spatial variability and scales of clouds above the CART site. This involved the SGP MMCR and several visiting radars at and near the Central Facility. The NOAA/K radar van became the operations center during the IOP by virtue of its realtime scan displays and radio communications facilities. NOAA/K scanned primarily in the RHI mode covering the azimuths toward the other visiting vertically pointing cloud radars. The scans produced nearly instantaneous vertical cross sections within about 25 km range of the Central Facility with a volume repetition time of about 2 minutes. An example scan image is shown in Figure 1. The RHI scans reveal the detailed vertical structure of the clouds, and,

in sequence, allow the temporal and spatial variability to be examined. Movie-loop images from the scans for several case study days are available for viewing on the internet at http://www6.etl.noaa.gov/data/arm2000/ .

Software is being developed to convert the NOAA/K data files from their raw tape format to netCDF files instead of to the traditional Common Doppler Radar Exchange Format ("universal format" or "UF") which has been used for most scanning research radars in the past. ETL and NCAR are working together to develop a fully compatible netCDF structure that will accommodate scanning radar and lidar data from both groups.

Cloud physics aircraft in-situ measurements from the IOP aircraft provide another data set for further evaluation of microphysical retrievals involving cloud radar and radiometer measurements. These aircraft measurements will be used to continue to assess retrievals, which ETL has developed in recent years and which it continues to refine for current and possible future use by ARM and CloudSat. ETL also used the IOP as an opportunity to conduct dual-antenna tests (described below) and tests of the attenuation caused when the radome is wet from heavy rainfall. The resulting data are being evaluated. The SGP radar was specially configured during the IOP for extensive Doppler spectrum recording and to allow a new PNL radar processor to tap into the spectra measurement data stream.

5b. Dual-Antenna System

Accurate radar reflectivity calibrations are important for the MMCR because all microphysical retrievals depend in part on the reflectivity measurement. The problem is particularly difficult because the MMCR antennas point vertically and can't be aimed at nearby calibration targets and they are too large to be reasonably transported to antenna calibration ranges. To address the problem, ETL is developing a small auxiliary antenna system for use with the MMCR. The small, easily transportable antenna can be calibrated at test facilities and then operated in tandem (switching alternate pulses) with the MMCRs large antenna during test periods to check the MMCR measurements. A 2-ft-diameter antenna has been purchased for this job and associated switching hardware has been developed. The system has been installed and tested on the SGP MMCR during the 2000 Cloud IOP and on the hot-spare MMCR. Evaluations of these data are underway.

5c. MMCR Maintenance and Upgrades

ETL completed construction of the "hot spare" MMCR in the fall of 1999. Radian, Intl., engineers learned assembly techniques from ETL on this unit and are now constructing the "ARCS-3" MMCR unit. Subsequently, parts from the hot spare have been swapped for a number of temporary repairs of CART-site radars. This included the electronic control and monitor chassis of the NSA radar that was damaged by a water leak from the roof and the transmitter unit (TWTA) for the SGP site. The damaged/ deteriorated parts were repaired at ETL or the manufacturer and installed in the hot spare. Software updates were made to the CART-site radars to make the calibration and data archiving routines functionally identical on all the field systems. This included installing the self-calibration hardware and software on the SGP radar. Electronic control circuitry was added to the SGP radar to prepare it for dual-polarization measurements; RF control circuitry still needs to be added for this purpose. A complete set of procedures for on-site back-up of CART-site MMCR computers is being developed at ETL following a security break-in by an unknown hacker to the Solaris computer in the SPG MMCR.

5d. Y2K Upgrades

Both computer systems used by the MMCRs required significant modifications to eliminate Y2K rollover problems affecting date codes attached to the data. Updates were written at ETL for the Solaris and OS/2 operating systems, radar control software, processing scripts, and UPS micro-code. ETL provided a field upgrade kit and installation procedures for use by the ARM technical staff which completed installation on all the CART-site radars by mid-January.

5e. Dual-polarization

In a separate contract, ETL is developing hardware and software to give the MMCR dual-polarization measurement capability. A study has also been conducted of how this capability can be used to identify low-altitude insects or other non-hydrometeor targets and distinguish them from stratus cloud droplets. A method for integrating the radar polarization information with Penn State University's ARSCL radar + lidar cloud masking algorithm has been described. The study shows that the cloud portion of the observed radar reflectivity from a cloud/insect mixture can be recovered with useful accuracy for at least some circumstances.

5f. Microphysical Retrieval Techniques

ETL continues to develop, refine, and assess methods for estimating microphysical characteristics of the clouds above the CART sites, based on concurrent cloud radar, microwave radiometer, and IR radiometer measurements. Work in the past year included further evaluations of the accuracy of liquid cloud parameter estimations using data from the Spring 1997 Cloud IOP and development of more widely applicable retrievals for stratus clouds and for cirrus.

6. Figures

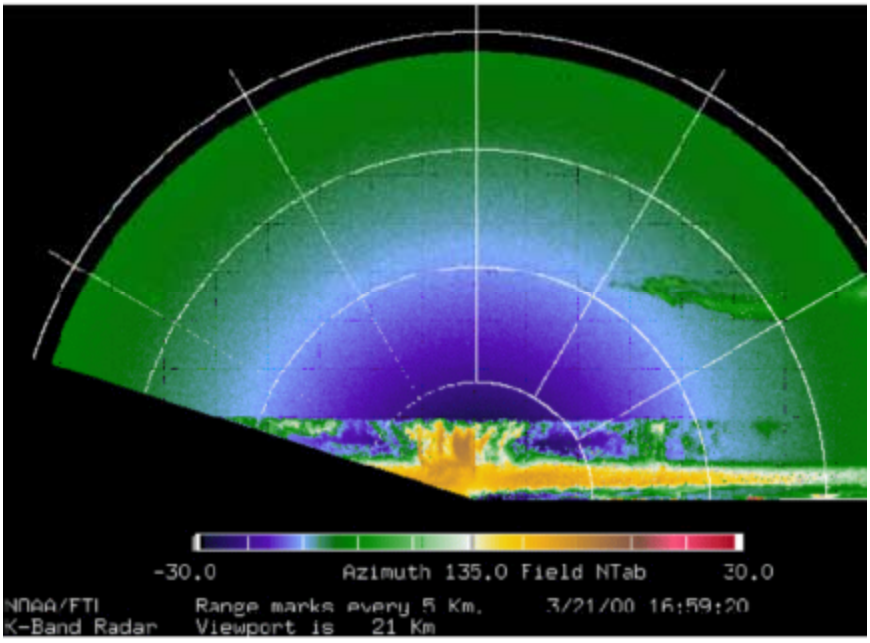

Figure 1. Example reflectivity image from an RHI scan of the NOAA/K cloud radar during the ARM 2000 Cloud IOP. This scan was oriented NW-SE. Range rings are at 5-km intervals. The scan shows an extensive stratus layer at about 1.5 km AGL, a precipitating, broken stratocumulus layer at about 3.5 km, and an isolated cirrus cloud at 9-10 km AGL. Data of this type were obtained during aircraft flights and at other times during the IOP to study the spatial and temporal variability of cloudiness.

7. New Refereed Publications

(Reprints will be mailed when these articles are in print.)

Frisch, A.S., B.E. Martner, I. Djalalova, and M. Poellot, 2000: Comparison of radar-radiometer retrievals of stratus cloud liquid water content with in-situ measurements by aircraft. *J. Geophys. Res.* (in press).

Martner, B.E., and K.P. Moran, 2000: Using cloud radar polarization measurements to evaluate stratus cloud and insect echoes. *J. Geophys. Res.* (submitted).

Matrosov, S.Y., and A.J. Heymsfield, 2000: The use of Doppler radar to assess ice cloud particle fall velocity-size relations for remote sensing and climate studies. *J. Geophys. Res.* (accepted).

White, A.B., J.R. Jordan, B.E. Martner, F.M. Ralph, and B.W. Bartram, 2000: Extending the dynamic range on an S-band radar for cloud and precipitation studies. *J. Atmos. and Oceanic Tech.* (in press).

8. New Extended Abstracts

Frisch, S., I. Djalalova, G. Feingold, and M. Poellot, 2000: On the retrieval of the effective radius in continental stratus clouds with cloud radars. *Proceedings, ARM Science Team Meeting,* San Antonio, TX.*

Martner, B., and K. Moran, 2000: MMCR polarization measurements for evaluating stratus cloud and insect echoes. *Proceedings, ARM Science Team Meeting,* San Antonio, TX.*

Matrosov, S.Y., and A.J. Heymsfield, 2000: Ice cloud fall velocity-size relations from Doppler radar measurements. *Proceedings, ARM Science Team Meeting,* San Antonio, TX.*

Moran, K., T. Ayers, B. Martner, M.J. Post, and K. Widener, 2000: Dual-polarization observations on an MMCR: Implementation and first results. *Proceedings, ARM Science Team Meeting,* San Antonio, TX.*

* = electronic version only, available for viewing at http://www.arm.gov/documents.technical/

9. Publication Update from Previous Report

All journal and conference articles to date from this project since October 1998 (FY99 and FY00).

Clothiaux, E.E., K.P. Moran, B.E. Martner, T.P. Ackerman, G.G. Mace, T. Uttal, J.H. Mather, K.B. Widener, M.A. Miller, and D.J. Rodriguez, 1999: The Atmospheric Radiation Measurement program cloud radars: Operational modes. *J. Atmos and Ocean. Tech*., 819-827.

Clothiaux, E.E., T.P. Ackerman, G.G. Mace, K.P. Moran, R.T. Marchand, M.A. Miller, and B.E. Martner, 2000: Objective determination of cloud heights and radar reflectivities using a combination of active remote sensors at the ARM CART sites. *J. Appl. Meteor.*, 645-665.

Clothiaux, E.E., B.E. Martner, T.P. Ackerman, K.P. Moran, and M.A. Miller, 1999: Cloud detection by radar and lidar at the ARM CART sites. *Proc. 29th Intl. Conf. on Radar Meteor.*, Montreal, Canada, 463-465.

Frisch, A.S., B.E. Martner, I. Djalalova, and M. Poellot, 2000: Comparison of radar-radiometer retrievals of stratus cloud liquid water content with in-situ measurements by aircraft. *J. Geophys. Res.* (in press).

Frisch, S., I. Djalalova, G. Feingold, and M. Poellot, 2000: On the retrieval of the effective radius in continental stratus clouds with cloud radars. *Proceedings, ARM Science Team Meeting,* San Antonio, TX.

Frisch, A.S., B.E. Martner, I. Djalalova, and M. Poellot, 1999: Comparison of radar-radiometer retrievals of stratus cloud liquid water content with in-situ measurements by aircraft. *Proc. 29th Intl. Conf. on Radar Meteor*., Montreal, Canada, 466-468.

Frisch, A.S., G. Feingold, C.W. Fairall, and J.B. Snider, 1998: On cloud radar and microwave radiometer measurements of cloud liquid water profiles. *J. Geophysical Res.*, **103**, 23,195-23,197.

Kropfli, R.A., B.E. Martner, S.Y. Matrosov, R.F. Reinking, A.S. Frisch, and T. Uttal, 1998: Radar and radiometer measurements of the physical parameters of clouds and precipitation at the NOAA Environmental Technology Laboratory. *Proc. Conf. on Battlespace Atmos. And Cloud Impacts on Military Operations*, Hanscomb AFB, MA, 125-132.

Lataitis, R.J., R.G. Strauch, K.P. Moran, and B.E. Martner, 1998: Near-field correction to the meteorological radar equation. *Proc. 4th Intl. Symp. On Tropospheric Profiling*, Snowmass, CO, 188-190.

Martner, B.E. and K.P. Moran, 2000: Using cloud radar polarization measurements to evaluate stratus cloud and insect echoes. *J. Geophys. Res.* (submitted).

Martner, B., and K. Moran, 2000: MMCR polarization measurements for evaluating stratus cloud and insect echoes. *Proceedings, ARM Science Team Meeting*, San Antonio, TX.

Martner, B.E., M.J. Post, and K.P. Moran, 1998: The MMCR unattended cloud-profiling radar: status update. *Proc. 4th Intl. Symp. On Tropospheric Profiling*, Snowmass, CO, 215-217.

Martner, B.E., M.J. Post, R.A. Kropfli, and K.P. Moran, 1998: The MMCR: A new cirrus research tool. *Tech. Digest, Cirrus Topical Meet.*, Optical Soc. of America, 5-7.

Matrosov, S.Y., and A.J. Heymsfield, 2000: The use of Doppler radar to assess ice cloud particle fall velocity-size relations for remote sensing and climate studies. *J. Geophys. Res.* (accepted).

Matrosov, S.Y., and A.J. Heymsfield, 2000: Ice cloud fall velocity-size relations from Doppler radar measurements. *Proceedings, ARM Science Team Meeting*, San Antonio, TX.

Matrosov, S.Y., and A.J. Heymsfield, 1999: Estimations of cirrus particle fall velocity-size relations from radar measurements. *Proc. 9th ARM Science Team Meet.*, San Antonio, TX.

Matrosov, S.Y., and R.A. Kropfli, 1998: Profiling cloud ice mass and particle size from radar and IR measurements using tuned regressions between reflectivity and cloud parameters. *Proc. 4th Intl. Symp. On Tropospheric Profiling*, Snowmass, CO, 218-220.

Matrosov, S.Y. and R.A. Kropfli, 1998: Retrievals of vertical profiles of cirrus microphysics from radar reflectivity and estimates of cloud optical thickness. *Tech. Digest, Cirrus Topical Meet.*, Optical Soc. of America, 11-13.

Moran, K., T. Ayers, B. Martner, MJ. Post, and K. Widener, 2000: Dual-polarization observations on an MMCR: Implementation and first results. *Proceedings, ARM Science Team Meeting*, San Antonio, TX.

Moran, K.P., B.E. Martner, M.J. Post, R.G. Strauch, D. Welsh, and K. Widener, 1999: Signal processing techniques used in the 8-mm-wavelength cloud radars. *Proc. 9th ARM Science Team Meet.*, San Antonio, TX.

Post, M.J., K.P. Moran, B.E. Martner, and K.B. Widener, 1998: Unattended 35-GHz cloud-profiling radar. *Proc. Conf. on Battlespace Atmos. And Cloud Impacts on Military Operations*, Hanscomb AFB, MA, 133-138.

White, A.B., J.R. Jordan, B.E. Martner, F.M. Ralph, and B.W. Bartram, 2000: Extending the dynamic range on an S-band radar for cloud and precipitation studies. *J. Atmos. and Oceanic Tech.* (in press).